

UND-HEP-01-BIG 02

CHARM PHYSICS AND THE POOR SLEEPER'S IMPATIENCE ¹

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Abstract

After a short review of the theoretical tools available to describe heavy flavour physics I sketch the present profile of the weak dynamics of charm hadrons with respect to lifetimes, oscillations and CP violation. I argue that comprehensive studies of charm decays provide novel portals to New Physics and suggest some benchmark figures for desirable sensitivities.

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¹Invited talk given at the 4th International Conference on B Physics and CP Violation, Ise, Japan, Feb. 19 - 23, 2001

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1 Introduction

There is a widespread perception that while charm physics had its days, those days are in the past, it has little to offer in new insights and all that remains is polishing the data. This is, however, a short-sighted view with respect to both production and decay of charm hadrons. I will focus on the latter to emphasize the following points:

- They provide us with a test bed for QCD technologies.
- Charm transitions are a unique portal for obtaining a novel access to the flavour problem with the experimental situation being a priori favourable.

Accordingly I will address the following topics: first I will give a lightning update on the status of QCD technologies relevant for heavy flavour decays; after sketching charm’s present profile I will stress its promise of revealing New Physics and combine it with an appeal to embark onto a comprehensive New Phenomenology emphasizing $D^0 - \bar{D}^0$ oscillations and CP violation.

2 QCD Technologies

While we have no solution of full QCD, we do have theoretical technologies inferred from QCD that allow us to deal with nonperturbative dynamics in special situations. Those are chiral perturbation theory for pion and kaon dynamics and heavy quark expansions (HQE). The latter apply to some aspects of the dynamics of beauty hadrons and possibly of charm hadrons as well. However since the charm quark mass exceeds ordinary hadronic scales by a moderate margin only, one can expect at best a semi-quantitative description there.

Simulating QCD on the lattice represents a technology of wide reach. In principle lattice QCD could work its way up to the charm scale from below. However the considerable advances achieved recently on the lattice with respect to heavy flavour physics were not based on such a ‘brute-force’ approach, but on a judicious choice of $1/m_Q$ expansions [1, 2]. The feedback between HQE and lattice QCD will yield even more gains in the future.

2.1 Heavy Quark Expansions

In HQE one describes an observable γ for a hadron H_Q – be it a total rate or a distribution – through an expansion in inverse powers of the heavy *quark* mass [4] m_Q :

$$\gamma(E) = \sum_i c_i(\alpha_S, E)(\Lambda_i/m_Q)^i ; \quad (1)$$

E denotes the relevant energy scale.

The crucial question in this context is whether an observable can be described through an operator product expansion (OPE) or not. Essential tools are provided by sum rules [5]

$$\int_0^\infty dE w(E) \gamma(E)|_{hadrons} = \int_0^\infty dE w(E) \gamma(E)|_{quarks} \quad (2)$$

stating that the integral of such observable γ weighted by some function $w(E)$ has to be equal when expressed in terms of hadronic or quark degrees of freedom.

These methods are applied to *inclusive* transitions – lifetimes, semileptonic branching ratios, lepton spectra etc. – and *exclusive* observables like semileptonic form factors and branching ratios for nonleptonic two-body modes. I would like to add here that there are several reasons why the recently suggested methods for $B \rightarrow M_1 M_2$ [6] are hard to justify for charm decays. Nevertheless one should try them there anyway!

When calculating a rate on the quark-gluon level *quark-hadron duality* (or duality for short) is invoked to equate the result with what one should get for the corresponding process expressed in hadronic quantities. Such duality represents a very natural concept. For the hadronic final state forms in two steps: a *hard* process controlled by a time scale $1/m_Q$ is followed by *soft* hadronization characterized by a time scale Λ in the rest frame of the heavy quark which gets time dilated into $\sim m_Q/\Lambda^2$ in the, say, c.m. frame.

Since $m_Q/\Lambda^2 \gg 1/m_Q$ the gross features of the process – total rates, energy flows etc. – are determined by the first step. Duality thus has to be exact at asymptotic scales; yet at finite scales there are corrections.

These features can nicely be illustrated by a quantum mechanical model involving a potential $V(\vec{x})$: while the local properties of the potential determine integrated rates², the asymptotic features (like confining or not) control the specifics of the final state.

While we have no complete theory yet for the limitations to duality, we have moved beyond a merely folkloric stage.

- We know that the duality violations at finite scales depend on the process under study.
- We have identified the mathematical portals for duality violations: the OPE constructed in the Euclidean regime cannot reproduce terms like $\exp(-m_Q/\Lambda)$ that are exponentially suppressed there. However upon analytic continuation into the Minkowski domain they get transmogrified into terms like $\sin(m_Q/\Lambda)$, which by themselves are not suppressed. It turns out though that duality violating terms are power suppressed, i.e. of the form $\sin(m_Q/\bar{\Lambda})/m_K^{k_i}$ with a positive power k_i that depends on the reaction.
- The fundamental question is whether one can base the description on an OPE or not rather than whether one deals with nonleptonic versus semileptonic transitions or whether one considers local duality. One expects duality violations to be numerically larger in the former than the latter class of processes, but not as a matter of principle!
- One particular and obvious problem for the charm sector: the expansion parameter Λ_i/m_c is not much smaller than unity since $m_c(m_c) = 1.25 \pm 0.1$ GeV. *At best* this introduces sizeable numerical uncertainties; *at worst* it could signal the breakdown of duality at or near the charm scale.

These insights are based on two types of sources:

²This connection can be broken, if the potential contains singularities at finite distances. This feature can be reproduced in a quantum field theory through instanton effects [7].

- We have developed a good understanding of the physical origins of duality violations as due to hadronic thresholds, the presence of ‘distant’ cuts and the $1/m_c$ expansions [8].
- Very extensive and detailed studies in model field theories like the ’t Hooft model have been performed over the last few years [9].

The final arbiter will be provided by data, of course, namely by *overconstraints* in measurements. One topical example is the beauty quark mass which can be extracted from the $\Upsilon(4S)$ mass and from the shape of the lepton spectra in semileptonic B decays. Present results are quite encouraging in that respect [10].

2.2 Lattice QCD

Lattice QCD, which was originally introduced to prove confinement and bring hadronic spectroscopy under theoretical control, is now making major contributions to heavy flavour physics – with partially unquenched results. For the D_s decay constant one finds for two active flavours [2]

$$f(D_s) = 255 \pm 30 \text{ MeV lattice QCD} \quad (3)$$

to be compared with what one infers from a world average of data on $D_s \rightarrow \mu\nu$ [3]: $\langle f(D_s) \rangle = 269 \pm 22 \text{ MeV}$; the experimental error is probably on the optimistic side.

In the future one expects to measure the D_s^+ and D^+ decay constants with 5 - 10 % accuracy at the beauty factories; a τ -charm factory would allow a 2-3 % measurement [11], which could be fully utilized since absolute branching ratios can be determined with the necessary accuracy at the same time. On the theoretical side a lattice study with full unquenching that treats charm quarks as dynamic rather than static entities is not utopian; likewise for the form factors in exclusive semileptonic charm decays. Charm decays will thus provide a rich lab for quantitative tests of lattice QCD.

More generally, the synergies produced by the feedback between HQE and lattice QCD and the calibration provided by the charm data will yield important lessons on QCD probing and hopefully extending our theoretical control over nonperturbative dynamics. Beyond being a very worthwhile motivation in itself, it will strengthen searches for New Physics.

3 Present Profile of the Weak Dynamics of Charm

3.1 Lifetimes

As explained at BCP3 [12] HQE produce a remarkably successful description of both the pattern and the numbers in the lifetime ratios. The HQE provide a rationale for most of the phenomenological concepts introduced before – like PI, WA etc. – as effects of order $1/m_Q^3$. Since it represents a self-consistent framework, it is more definitive about those concepts. For example WA has to be a nonleading effect although it could still be significant.

HQE also explain – as a new and highly welcome feature – the absolute sizes of the semileptonic branching ratios as effects of order $1/m_Q^2$ – something that previous models could not.

The one new result of the last two years is [13, 17]

$$\tau(D_s)/\tau(D^0) = 1.18 \pm 0.02 \quad (4)$$

rather than the previous world average of 1.125 ± 0.042 . It confirms that WA is *not the leading* source of lifetimes differences among charm mesons; at the same time it shows WA to be still significant at the about 20 % level, as expected. It leads to the further question whether this difference in total widths can be traced to certain classes of exclusive channels.

The accuracy in the data on $\tau(\Xi_c^{0,+})$ and $\tau(\Omega_c)$ leaves much to be desired before firm conclusions can be based on them. One should also remember that the semileptonic *widths* of charm baryons do not mirror their lifetime ratios since the semileptonic widths are *not* universal for baryons [14].

3.2 Cabibbo Hierarchy

The full range of the Cabibbo pattern has been observed in nonleptonic as well as semileptonic transitions.

Imposing three-family unitarity leads to numerically very precise values of the CKM parameters:

$$|V(cs)| = 0.9742 \pm 0.0008, \quad |V(cd)| = 0.222 \pm 0.003 \quad (5)$$

Without that constraint the values are less precise:

$$|V(cs)| = 0.880 \pm 0.096, \quad |V(cd)| = 0.226 \pm 0.007 \quad (6)$$

As far as $|V(cs)|$ is concerned the main information from semileptonic D decays is augmented by findings from charm production in deep inelastic neutrino scattering; for $|V(cd)|$ it is the other way around. A recent OPAL analysis of $W \rightarrow$ charm jets obtains

$$|V(cs)| = 0.969 \pm 0.058 \quad (7)$$

3.3 Data on $D^0 - \bar{D}^0$ Oscillations

Oscillations are described by the normalized mass and width differences: $x_D \equiv \frac{\Delta M_D}{\Gamma_D}$, $y_D \equiv \frac{\Delta \Gamma}{2\Gamma_D}$. The experimental landscape is described by the following numbers [16, 17]:

$$x_D \leq 0.03 \quad (8)$$

$$y_D = \begin{cases} (0.8 \pm 2.9 \pm 1.0)\% & \text{E791} \\ (3.42 \pm 1.39 \pm 0.74)\% & \text{FOCUS} \\ (1.16^{+1.67}_{-1.65})\% & \text{BELLE} \\ (-1.1 \pm 2.5 \pm 1.4)\% & \text{CLEO} \end{cases} \quad (9)$$

$$y'_D = (-2.5^{+1.4}_{-1.6} \pm 0.3)\% \quad \text{CLEO} . \quad (10)$$

y'_D is extracted from fitting a general lifetime evolution to $D^0(t) \rightarrow K^+\pi^-$ and depends on the strong rescattering phase δ between $D^0 \rightarrow K^-\pi^+$ and $D^0 \rightarrow K^+\pi^-$: $y'_D = -x_D \sin \delta + y_D \cos \delta$. It could differ substantially from y_D if that phase were sufficiently large [18]. All measurements are still consistent with zero.

3.4 CP Asymmetries – Data

Data are summarized in Table 1 [15, 16]. The experimental sensitivity has increased significantly to put us within striking distance of the 1% level. Yet the numbers are still consistent with zero.

channel	$D^0 \rightarrow K^+ K^-$	$D^0 \rightarrow \pi^+ \pi^-$
E 791	$-1.0 \pm 4.9 \pm 1.2\%$	$-4.9 \pm 7.8 \pm 3.0\%$
CLEO	$0.05 \pm 2.18 \pm 0.84\%$	$1.95 \pm 3.22 \pm 0.84\%$
FOCUS	$-0.1 \pm 2.2 \pm 1.5\%$	$4.8 \pm 3.9 \pm 2.5\%$
channel	$D^\pm \rightarrow K^+ K^- \pi^\pm$	
E 791	$-1.4 \pm 2.9\%$	
FOCUS	$0.6 \pm 1.1 \pm 0.5\%$	

Table 1: Data on direct CP asymmetries in D decays

4 Charm Decays – Novel Portals to New Physics

Obviously there is unfinished business in charm physics: one wants to measure *absolute* branching ratios more precisely, in particular for D_s and charm baryons; likewise for $\Xi_c^{0,+}$ and Ω_c lifetimes and semileptonic branching ratios. As already mentioned, more accurate data on D^+ , $D_s^+ \rightarrow l^+ \nu$ are very desirable – as are post-MARK III data on lepton *spectra* in *inclusive* semileptonic charm decays. All these can provide important inputs to beauty studies and some can give us important lessons on QCD as well.

But that is not the end of it! There is a wide-spread conviction in the community that the SM is incomplete, and our efforts are focussed on uncovering New Physics. It seems to me that charm decays have a good potential to reveal manifestations of New Physics that might not be manifest in beauty decays. For charm quarks are the only up-type quark allowing a full range of indirect searches for New Physics. While $D^0 - \bar{D}^0$ oscillations are slow, $T^0 - \bar{T}^0$ oscillations cannot occur at all, nor can CP violation there, since top quarks decay before they can hadronize [19]. Direct CP violation can emerge in exclusive modes that command decent branching ratios for charm, but are really tiny for top with little coherence left.

Finally charm decays proceed in an environment populated with many resonances which induce final state interactions (FSI) of great vibrancy. While this feature complicates the interpretations of a signal (or lack thereof) in terms of microscopic quantities, it is optimal for getting an observable signal. In that sense it should be viewed as a glass half full rather than half empty.

Charm hadrons provide several practical advantages and opportunities:

their production rates are relatively large; they possess long lifetimes and $D^* \rightarrow D\pi$ decays provide as good a flavour tag as one can have.

This leads to my basic contention: charm transitions are a *unique* portal for obtaining a *novel* access to the *flavour* problem with the *experimental situation being a priori mostly favourable!*

4.1 $D^0 - \bar{D}^0$ Oscillations – Revisited

While all present data are consistent with both x_D and y_D being zero, we have to examine how significant that statement is, i.e. what the SM expectations are.

With $D^0 \rightarrow f \rightarrow \bar{D}^0$ transition amplitudes being proportional to $\sin\theta_C^2$ one has $x_D, y_D \leq 0.05$; furthermore in the limit of $SU(3)_{Fl}$ symmetry those amplitudes have to vanish. However a priori one cannot count on that being a very strong suppression for the real world; thus $x_D, y_D \sim \mathcal{O}(0.01)$ represents a conservative SM bound. On general grounds I find it unlikely – though mathematically possible – that New Physics could overcome the Cabibbo bound significantly. Comparing this general bound on the oscillation variables to the data listed in Eq.(9), I conclude the hunt for New Physics realistically has only just begun!

One can give a more sophisticated SM estimate for x_D, y_D . There exists an extensive literature on it [20]; however some relevant features were missed for a long time. Quark box diagrams yield tiny contributions only:

$$x_D(\text{box}) \sim \text{few} \times 10^{-5} \quad (11)$$

Various schemes are then invoked to describe selected hadronic intermediate states to guestimate the impact of long distance dynamics:

$$x_D(LD), y_D(LD) \sim 10^{-4} - 10^{-3} \quad (12)$$

Recently a new analysis [21] has been given based on an OPE providing a systematic treatment in powers of $1/m_c$, the GIM factors m_s and the CKM parameters. It finds that the the GIM suppression by a factor of $(m_s/m_c)^4$, which is behind the result stated in Eq.(11) is *untypically severe* [22]. It was found that there are contributions with gentle GIM factors proportional to m_s^2/μ_{had}^2 or even m_s/μ_{had} . They are due to higher-dimensional operators and thus accompanied by higher powers of $1/m_c$. Since those are not greatly

suppressed, contributions of formally higher order in $1/m_c$ can become numerically leading if they are of lower order in m_s . These contributions are actually due to condensate terms in the OPE, namely $\langle 0|\bar{q}q|0\rangle$ etc. On the *conceptual* side we have achieved significant progress: it is again the OPE that allows to incorporate nonperturbative dynamics from the start in a self-consistent way. *Numerically* there is no decisive change, although the numbers are somewhat larger:

$$x_D(SM)|_{OPE}, y_D(SM)|_{OPE} \sim \mathcal{O}(10^{-3}) \quad (13)$$

However one realizes that it is rather unlikely that the uncertainties can significantly be reduced, since the values depend on a high power of some hadronic quantities.

The crucial question is: does duality hold at the charm scale for x_D and y_D ? Those two observables are sensitive to different aspects of $\Delta C = 2$ dynamics: (i) The normalized width difference is determined by on-shell transitions and has very little chance to be affected by New Physics; on the other hand it can be strongly affected by a near-by resonance. Whether duality has any validity for the observable y_D is quite unclear a priori. (ii) The mass difference on the other hand is controlled by virtual transitions. Thus it has a good chance to be shaped by New Physics leading to $x_D \sim \mathcal{O}(\text{few}\%)$; at the same time it involves more smearing than y_D ; therefore duality has a much better chance to apply approximately to x_D than to y_D .

If data revealed $y_D \ll x_D \sim 1\%$ we would have a strong case to infer the intervention of New Physics. If on the other hand $y_D \sim 1\%$ – as hinted at by the FOCUS data – then two scenarios could arise: if $x_D \leq \text{few} \times 10^{-3}$ were found, one would infer that the $1/m_c$ expansion within the SM yields a correct semiquantitative result while blaming the "large" value for y_D on a sizeable and not totally surprising violation of duality. If, however, $x_D \sim 0.01$ would emerge, we would face a theoretical conundrum: an interpretation ascribing this to New Physics would hardly be convincing since $x_D \sim y_D$. To base a case for New Physics solely on the observation of $D^0 - \bar{D}^0$ oscillations is thus of uncertain value.

4.2 CP Violation – Expectations

(i) Direct CP Violation in Partial Widths

For an asymmetry to become observable between CP conjugate partial widths, one needs two coherent amplitudes with a relative *weak* phase and a nontrivial strong phase shift.

In Cabibbo favoured as well as in doubly Cabibbo suppressed channels those requirements can be met with New Physics only. There is one exception to this general statement [23]: the transition $D^\pm \rightarrow K_S \pi^\pm$ reflects the interference between $D^+ \rightarrow \bar{K}^0 \pi^+$ and $D^+ \rightarrow K^0 \pi^+$ which are Cabibbo favoured and doubly Cabibbo suppressed, respectively. Furthermore in all likelihood those two amplitudes will exhibit different phase shifts since they differ in their isospin content. The known CP impurity in the K_S state induces a difference without any theory uncertainty:

$$\frac{\Gamma(D^+ \rightarrow K_S \pi^+) - \Gamma(D^- \rightarrow K_S \pi^-)}{\Gamma(D^+ \rightarrow K_S \pi^+) + \Gamma(D^- \rightarrow K_S \pi^-)} = -2\text{Re}\epsilon_K$$

$$\simeq -3.3 \cdot 10^{-3} \quad (14)$$

In that case the same asymmetry both in magnitude as well as sign arises for the experimentally much more challenging final state with a K_L . If on the other hand New Physics is present in $\Delta C = 1$ dynamics, most likely in the doubly Cabibbo transition, then both the sign and the size of an asymmetry can be different from the number in Eq.(14), and by itself it would make a contribution of the opposite sign to the asymmetry in $D^+ \rightarrow K_L \pi^+$ vs. $D^- \rightarrow K_L \pi^-$.

Searching for *direct* CP violation in Cabibbo suppressed D decays as a sign for New Physics would also represent a very complex challenge: within the KM description one expects to find some asymmetries of order 0.1 %; yet it would be hard to conclusively rule out some more or less accidental enhancement due to a resonance etc. raising an asymmetry to the 1% level. Observing a CP asymmetry in charm decays would certainly be a first rate discovery even irrespective of its theoretical interpretation. Yet to make a case that a signal in a singly Cabibbo suppressed mode reveals New Physics is quite iffy. In all likelihood one has to analyze at least several channels with comparable sensitivity to acquire a measure of confidence in one's interpretation.

(ii) Direct CP Violation in Final State Distributions

For channels with two pseudoscalar mesons or a pseudoscalar and a vector meson a CP asymmetry can manifest itself only in a difference between the

two partial widths. If, however, the final state is more complex – being made up by three pseudoscalar or two vector mesons etc. – then it contains more dynamical information than expressed by its partial width, and CP violation can emerge also through asymmetries in final state distributions. One general comment still applies: since also such CP asymmetries require the interference of two weak amplitudes, within the SM they can occur in Cabibbo suppressed modes only.

In the simplest such scenario one compares CP conjugate *Dalitz plots*. It is quite possible that different regions of a Dalitz plot exhibit CP asymmetries of varying signs that largely cancel each other when one integrates over the whole phase space. I.e., subdomains of the Dalitz plot could contain considerably larger CP asymmetries than the integrated partial width.

Once a Dalitz plot is fully understood with all its resonance and non-resonance contributions including their strong phases, one has a powerful and sensitive new probe. This is not an easy goal to achieve, though, in particular when looking for effects that presumably are not large. It might be more promising as a practical matter to start out with a more heuristic approach. I.e., in the spirit of Yogi Berra one can start a search for CP asymmetries by just looking at conjugate Dalitz plots. One simple strategy would be to focus on an area with a resonance band and analyze the density in stripes *across* the resonance as to whether there is a difference in CP conjugate plots.

For more complex final states containing four pseudoscalar mesons etc. other probes have to be employed. Consider for example $D^0 \rightarrow K^+ K^- \pi^+ \pi^-$, where one can form a T-odd correlation with the momenta: $C_T \equiv \langle \vec{p}_{K^+} \cdot (\vec{p}_{\pi^+} \times \vec{p}_{\pi^-}) \rangle$. Under time reversal T one has $C_T \rightarrow -C_T$ hence the name ‘T-odd’. Yet $C_T \neq 0$ does not necessarily establish T violation. Since time reversal is implemented by an *antiunitary* operator, $C_T \neq 0$ can be induced by final state interactions (FSI). While in contrast to the situation with partial width differences FSI are not required to produce an effect, they can act as an ‘imposter’ here, i.e. induce a T-odd correlation with T-invariant dynamics. This ambiguity can unequivocally be resolved by measuring $\bar{C}_T \equiv \langle \vec{p}_{K^-} \cdot (\vec{p}_{\pi^-} \times \vec{p}_{\pi^+}) \rangle$ in $\bar{D}^0 \rightarrow K^+ K^- \pi^+ \pi^-$; finding $C_T \neq -\bar{C}_T$ establishes CP violation without further ado.

Decays of *polarized* charm baryons provide us with a similar class of observables; e.g., in $\Lambda_c \uparrow \rightarrow p \pi^+ \pi^-$, one can analyse the T-odd correlation $\langle \vec{\sigma}_{\Lambda_c} \cdot (\vec{p}_{\pi^+} \times \vec{p}_{\pi^-}) \rangle$ [24].

(iii) CP violation involving $D^0 - \bar{D}^0$ oscillations

The interpretation is much clearer once one finds a CP asymmetry that involves oscillations; i.e., one compares the time evolution of transitions like $D^0(t) \rightarrow K_S \phi, K^+ K^-, \pi^+ \pi^-$ and/or $D^0(t) \rightarrow K^+ \pi^-$ with their CP conjugate channels. A difference for a final state f would depend on the product

$$\sin(\Delta m_D t) \cdot \text{Im} \frac{q}{p} [T(\bar{D} \rightarrow f)/T(D \rightarrow \bar{f})] . \quad (15)$$

With both factors being $\sim \mathcal{O}(10^{-3})$ in the SM with the KM ansatz one predicts a practically zero asymmetry $\leq 10^{-5}$. Yet New Physics could quite conceivably generate considerably larger values, namely $x_D \sim \mathcal{O}(0.01)$, $\text{Im} \frac{q}{p} [T(\bar{D} \rightarrow f)/T(D \rightarrow \bar{f})] \sim \mathcal{O}(0.1)$ leading to an asymmetry of $\mathcal{O}(10^{-3})$. One should note that the oscillation dependant term is linear in the small quantity x_D

$$\sin \Delta m_D t \simeq x_D t / \tau_D \quad (16)$$

in contrast to r_D which is quadratic:

$$r_D \equiv \frac{D^0 \rightarrow l^- X}{D^0 \rightarrow l^+ X} \simeq \frac{x_D^2 + y_D^2}{2} \quad (17)$$

It would be very hard to see $r_D = 10^{-4}$ in CP insensitive rates. It could then well happen that $D^0 - \bar{D}^0$ oscillations are first discovered in such CP asymmetries!

5 Summary and Outlook

We have learnt many important lessons from charm studies. Yet even so, they do not represent a closed chapter.

On one hand charm physics can teach us many more important lessons about QCD and its nonperturbative dynamics beyond calibration work needed for a better analysis of beauty decays. On the other it provides a unique portal to New Physics through up-type quark dynamics with many, though not all, experimental features favourable.

In this latter quest only now have we begun to enter promising territory, namely gaining sensitivity for x_D and y_D values of order percent and likewise for CP asymmetries.

Without a clearcut theory of New Physics one has to strike a balance between the requirements of feasibility and the demands of making a sufficiently large step beyond what is known when suggesting benchmark numbers for the experimental sensitivity to aim at. In that spirit I suggest the following numbers: (i) Probe $D^0 - \bar{D}^0$ oscillations down to $x_D, y_D \sim \mathcal{O}(10^{-3})$ corresponding to $r_D \sim \mathcal{O}(10^{-6} - 10^{-5})$. (ii) Search for *time dependant* CP asymmetries in $D^0(t) \rightarrow K^+K^-, \pi^+\pi^-, K_S\phi$ down to the 10^{-4} level and in the doubly Cabibbo suppressed mode $D^0(t) \rightarrow K^+\pi^-$ to the 10^{-3} level. (iii) Look for asymmetries in the partial widths for $D^\pm \rightarrow K_{S[L]}\pi^\pm$ down to 10^{-3} and likewise in a *host* of singly Cabibbo suppressed modes. (iv) Analyze Dalitz plots and T-odd correlations etc. with a sensitivity down to $\mathcal{O}(10^{-3})$.

Huge amounts of new information on charm dynamics will become available due to data already taken by FOCUS and SELEX and being taken at the B factories; there is activity to be hoped for at Compass, BTeV and LHC-B. And finally there are the ‘gleam in the eye’ activities that could be performed at a tau-charm factory at Cornell. We can be sure to learn many relevant lessons from such studies – and there may be surprises when we least expect it as expressed by the following allegory:

‘The poor sleeper’s impatience’

A man wakes up at night,

Sees it is dark outside and falls asleep again.

A short while later he awakes anew,

Notices it still to be dark outside and goes back to sleep.

This sequence repeats itself a few times

– waking up, seeing the dark outside and falling asleep again –

Till he cries out in despair:

”Will there never be daylight?”

Acknowledgments

Many thanks go to Tony Sanda and his team for organizing an inspiring meeting in a beautiful and thus appropriate setting. This work has been supported by the NSF under the grants PHY 96-05080 and INT-0089550.

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